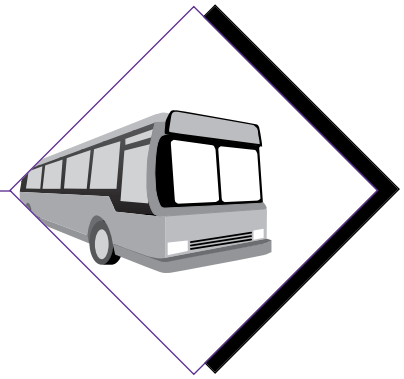
Alternative Fuel Transit Buses



Introduction

Overview

Recognizing the need to address the impacts of U.S. fuel consumption on national security, the economy, and the environment, Congress established a goal of reducing the nation's dependence on gasoline and diesel fuel. To ensure that this goal is met, Congress enacted the Alternative Motor Fuels Act (AMFA) of 1988. AMFA requires the U.S. Department of Energy (DOE) to collect data on alternative fuel vehicles—including transit buses—to evaluate their performance and cost. DOE designated the National Renewable Energy Laboratory (NREL) as the program manager for the data collection and vehicle evaluation program. NREL makes data on alternative fuel vehicles available to the public through the Alternative Fuels Data Center (AFDC). Staffers of the National Alternative Fuels Hotline (1-800-423-1DOE) can tell you how to connect to the AFDC and can retrieve information from the data center for you.

The transit bus program is designed to provide a comprehensive study of the alternative fuels currently used by the transit bus industry. The study focuses on the reliability, fuel economy, operating costs, and emissions of vehicles running on the various fuels and alternative fuel engines.

Buses in the Program

To obtain the detailed information needed for the study, we selected transit agencies that met the following criteria:

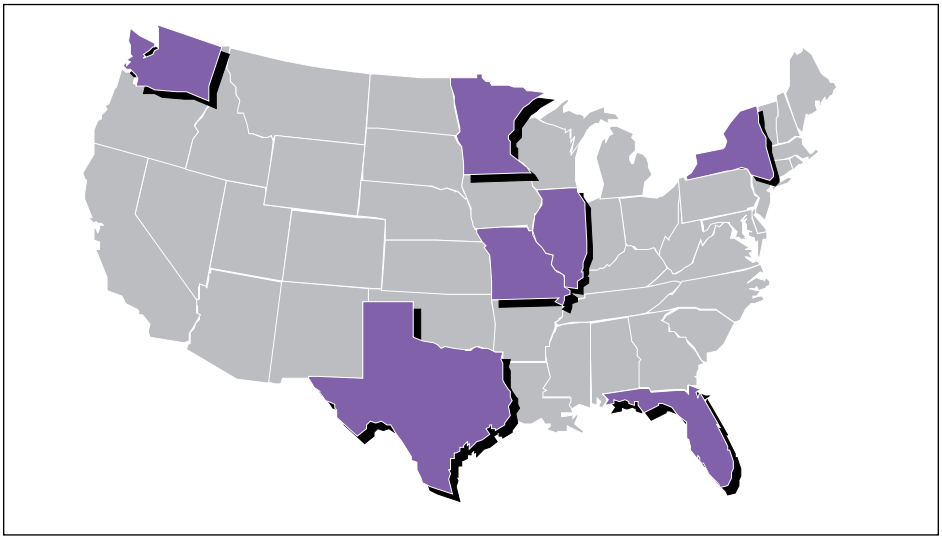


Figure 1. The program tests alternative fuel buses in seven municipalities across the nation.

- The transit agency had to have test buses that represented the most current technology available at the time.
- The transit agency had to have control buses that were identical to the alternative fuel buses, except for the fuel system they use.
- The transit agency personnel had to agree to supply detailed data on the vehicles for several years.

Using these criteria, we chose to test buses in seven metropolitan areas: Houston, Texas; Miami, Florida;

Alternative Fuel Transit Buses

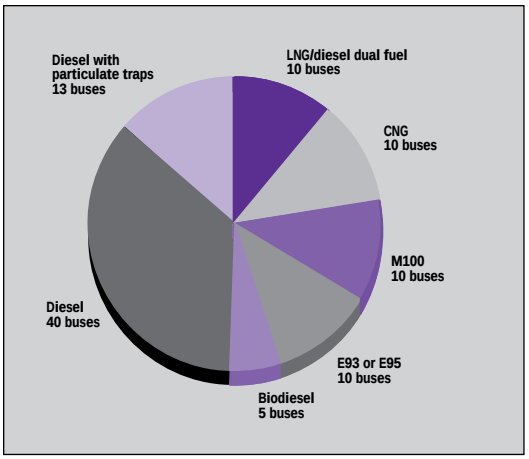


Figure 2. The number of test buses of each fuel type

Figure 3. The University of West Virginia uses its transportable chassis dynamometer to conduct emissions tests at each of the sites.

Minneapolis/St. Paul, Minnesota; New York, New York; Peoria, Illinois; St. Louis, Missouri; and Tacoma, Washington (see Figure 1). We are currently studying five alternative fuels—compressed natural gas (CNG), liquefied natural gas (LNG), 100% methanol (M100), 95% and 93% ethanol (E95 and E93), and a mixture of 80% conventional diesel and 20% biodiesel (BD20). Each of the alternative fuels being tested in the program is described in the sidebar on page 4. Note that BD20 is not currently considered an alternative fuel under the Energy Policy Act of 1992. Figure 2 shows the number of test buses of each fuel type. A program target was to test ten buses of each alternative fuel with ten controls, split between two sites. For example, there are 10 Cummins L10 CNG engines in the program, with 10 matching controls, split equally between Miami and Tacoma. Table 1 summarizes the transit buses in the program.

The alternative fuel buses in this program use the most common alternative fuel engines available from the heavy-duty engine manufacturers. In their diesel configuration, these engines are also the most common engines used by the transit bus industry. The engines are:

- Detroit Diesel 6V92TA methanol engine
- Detroit Diesel 6V92TA ethanol engine
- Detroit Diesel 6V92TA pilot ignition natural gas (PING) engine
- Cummins L10 natural gas engine.

The biodiesel buses use BD20 fuel in an unaltered Detroit Diesel Corporation 6V92TA engine. Each of the engines in the program has a horsepower rating of between 240 and 300. Buses in the program are 35-foot and 40-foot models manufactured by Stewart & Stevenson, Flxible, Gillig, TMC, and BIA.

Detroit Diesel Corporation recently introduced a CNG version of its Series 50 diesel engine. We plan to add Series 50 CNG engines to the program in the near future.

Table 1. Summary of Buses in the Program

City (Agency)	Engine	Alternative Fuel/Technology							Total	Bus Description
		M100	E93/ E95	LNG PING*	CNG SI**	BD20	Diesel w/trap***	Diesel Control		
Houston, TX (Houston Metro)	Detroit Diesel 6V92			10				5	15	40 ft Stewart & Stevenson
Miami, FL (Metro-Dade)	Detroit Diesel 6V92	5						5	10	40 ft Flxible
Miami, FL (Metro-Dade)	Cummins L10				5		5	10	20	40 ft Flxible
Minneapolis/St. Paul, MN (MCTO)	Detroit Diesel 6V92		5				5	5	15	40 ft Gillig
Peoria, IL (GP Transit)	Detroit Diesel 6V92		5				3		8	35 ft TMC
Tacoma, WA (Pierce Transit)	Cummins L10				5			5	10	40 ft BIA
New York, NY (New York City Dept. of Trans./ Triboro)	Detroit Diesel 6V92	5							5	40 ft TMC
	Detroit Diesel Series 50							5	5	40 ft TMC
St. Louis (Bi-State)	Detroit Diesel 6V92					5		5	10	40 ft Flxible
Total		10	10	10	10	5	13	40	98	

* Pilot ignition natural gas
** Spark ignited
*** Particulate trap

M100 = 100 percent methanol
E93 = 93 percent ethanol
E95 = 95 percent ethanol

LNG = Liquefied natural gas
CNG = Compressed natural gas
BD20 = 20% biodiesel and 80% diesel blend

Data Collected

Data are collected in four categories:

Bus and Route Descriptions—detailed descriptions of each vehicle in the program as well as a general description of the bus routes.

Bus Operating Data—descriptions and costs of all repair and maintenance work done on the buses. All fuel and oil put in the buses is recorded. We also record any safety incidents or safety-related information.

Emissions Data—from emissions tests conducted by West Virginia University (WVU) personnel, who visit each site and test emissions on the buses using WVU's transportable chassis dynamometer (shown in Figure 3).

Capital Costs—descriptions of the alternative fuel facilities, and facility cost at each site. We also record the incremental cost of the alternative fuel buses.

A subcontractor collects the daily operational data from the transit

The Alternative Fuels Being Tested

Methanol. Methanol is an alcohol produced primarily from natural gas, but it can also be derived from biomass or coal. For this reason, the domestic resource base for methanol is vast. The methanol buses in the program run on 100% methanol.

Ethanol. Ethanol is an alcohol derived from biomass (corn, sugar cane, grasses, trees, and agricultural waste). The ethanol used in the test buses was E93 (93% ethanol, 5% methanol, and 2% kerosene) or E95 (95% ethanol and 5% unleaded gasoline).

Biodiesel. Biodiesel fuel can be derived from any plant- or animal-derived oil product. The biodiesel blend used in the test buses, called BD20, was 20% biodiesel from soybeans and 80% diesel fuel. (Note: BD20 is not currently considered an alternative fuel under the Energy Policy Act of 1992).

Natural Gas. Natural gas is composed primarily of methane. It can be stored on the vehicle as a compressed gas or as a cryogenic liquid. The program includes vehicles that employ both types of storage.

agencies, converts the information into a standard form for submission to the data center, and analyzes the results. AFDC personnel then make the data available to the public through a series of data base queries and descriptions designed to present the information in a concise and logical format. Reports are also available over the Internet using Worldwide Web browsers such as Mosaic and Netscape. The internet address for the AFDC is:

http://www.afdc.nrel.gov:70/

Our goal is to collect 18 months of data on each test bus. Currently, we have approximately 18 months of data for only three of the seven sites. This report summarizes the interim results from the project to date. A more detailed interim report of the program will be available at a later date from the National Alternative Fuels Hotline.

In the sections that follow, we address the performance and reliability, fuel economy, costs, and emissions of the buses in the program. Other considerations for transit agencies are also covered. The final sections of the report outline the future plans for the program, including potential new sites with alternative fuel transit buses, and summarize the interim results.

Reliability

One measure of reliability in a bus is the average number of miles a bus travels between road calls. When the driver cannot complete a route because of a problem with the bus and calls for a replacement bus, a road call is recorded. Road calls encompass all types of events from engine failure to simply running out of fuel. Figure 4 shows the miles between road calls for the buses in the test program. The sections that follow provide a discussion of reliability by fuel type.

Liquefied Natural Gas

As seen in Figure 4, the dual-fuel buses in Houston running on LNG and diesel are experiencing considerably more road calls than the diesel controls—about 1,800 miles between road calls for LNG versus 3,300 miles between road calls for diesel. These roads calls are due mainly to two problems: the buses ran out of fuel (63 out of 213 total road calls), or the monitoring system detected a fuel leak and shut down the bus (44 out of 213). If a fuel problem develops with the LNG, the dual-fuel engines will switch to diesel as a backup. Because the dual-fuel buses have very small diesel